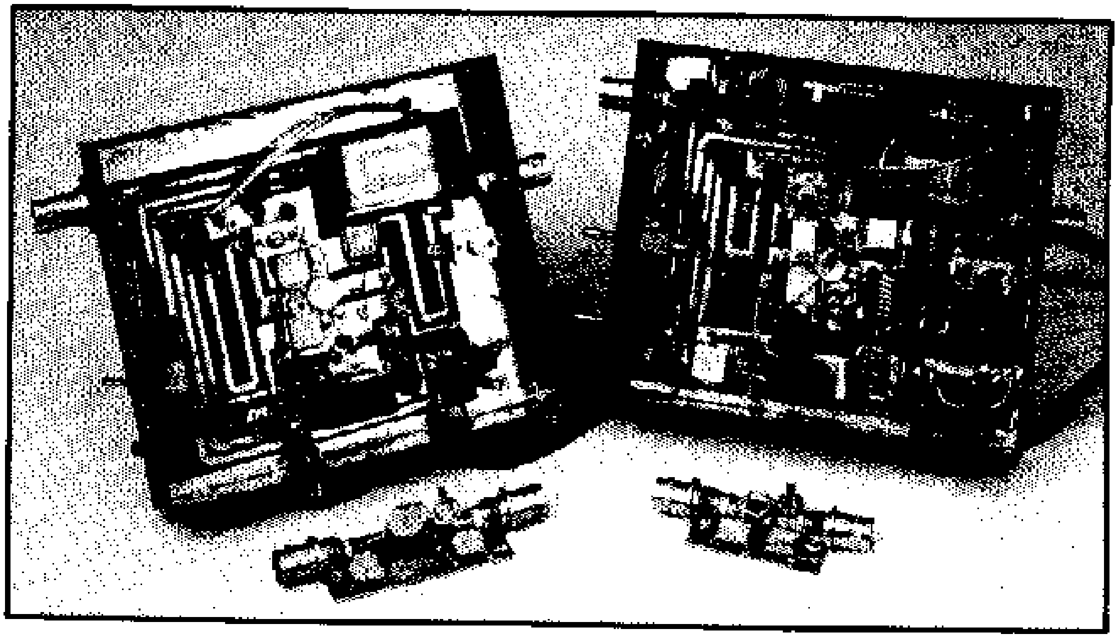
# 25-Watt Linear Amplifiers for 144 and 220 MHz



Do you need more punch from your hand-held or portable rig for 2 meters or 220 MHz? These little amplifiers can supply it!

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Many hams have 2-meter and 220-MHz hand-held rigs and low-power portable SSB rigs these days. Unfortunately, many of these radios have limited usefulness because of their low power output. Also, as hand-held radios get smaller, so do the NiCd packs that power them—a few long-winded transmissions on high power and the battery is dead! The low-power mode is usually good only for short-range simplex operation, or repeater use when you're close to the repeater. High-capacity battery packs are available for most hand-held rigs, but using them takes away the size and weight advantage of today's smaller hand-held transceivers. Some rigs offer the option of removing the battery pack and plugging the unit directly into 12-V dc, which gives you a small, lightweight rig, but you're still stuck with relatively low power.

The solution to this problem is the addition of a linear amplifier. An amplifier after the hand-held transceiver or portable rig that can give you 25 to 30 W of output power (depending on the output of the driving rig) without imposing large weight, cost and current-drain constraints is a great addition to your VHF station. An amplifier also allows you to use the same low-powered rig in the house and in the car with high power output. You can mount an amplifier under the seat or in the trunk of your car, and minimize the possibility of theft by taking the radio with you when you leave the car.

### Amplifier Design

The amplifiers described in this article are capable of 25 to 30 W of RF output for the drive power available from common hand-held and portable rigs. The 2-meter and 220-MHz designs are so similar that we can describe them both in one discussion. The differences in the designs are covered in detail. Design, assembly, tuning and use of the amplifiers is virtually identical for both versions. Both versions even use the same PC board! (Note that two different boards are shown in the lead photo—they were prototypes of the final board design.)

Receiving preamplifiers are included in both units. They, too, are quite similar, differing only in some component values.

This power amplifier uses a single SD1274 bipolar transistor manufactured by Thomson Components/Mostek Corp.[1] The device is operated class AB for all-mode operation. Nominal dc power supply voltage is 13.8. The amplifier will operate on any dc supply voltage between 12 and 14.5 (the typical automobile supply voltage range).

The main amplifier PC board is a microstripline design on standard 1/16-inch-thick, double-sided, G-10 fiberglass-epoxy board. Input and output tuning capacitors are provided for maximizing gain and power output in a given band segment. If desired, the amplifiers can be tuned for broadband operation with only a slight reduction in power output across the operating frequency range.

The 2-meter and 220-MHz amplifiers are narrow-band designs. The 2-meter version gives 25 W output for 2 W of drive from 138 to 150 MHz, with a single tuning setting. When tuned for narrow-band operation, the amplifier gives about 20 W output for 1 W of drive. With the Kenwood TH-21AT on high power, my 2-meter amplifier puts out 25 W. On low power, I can adjust the amplifier for a maximum narrow-band gain, which gives about 7 to 8 W output. Efficiency is 50 to 60%, depending on tuning and power output.

The tuning range of the 220-MHz amplifier is 200 to 230 MHz. When tuned for narrow-band operation, the amplifier gives about 16 W output for 1 W of drive.

[1]Notes appear on p 21.

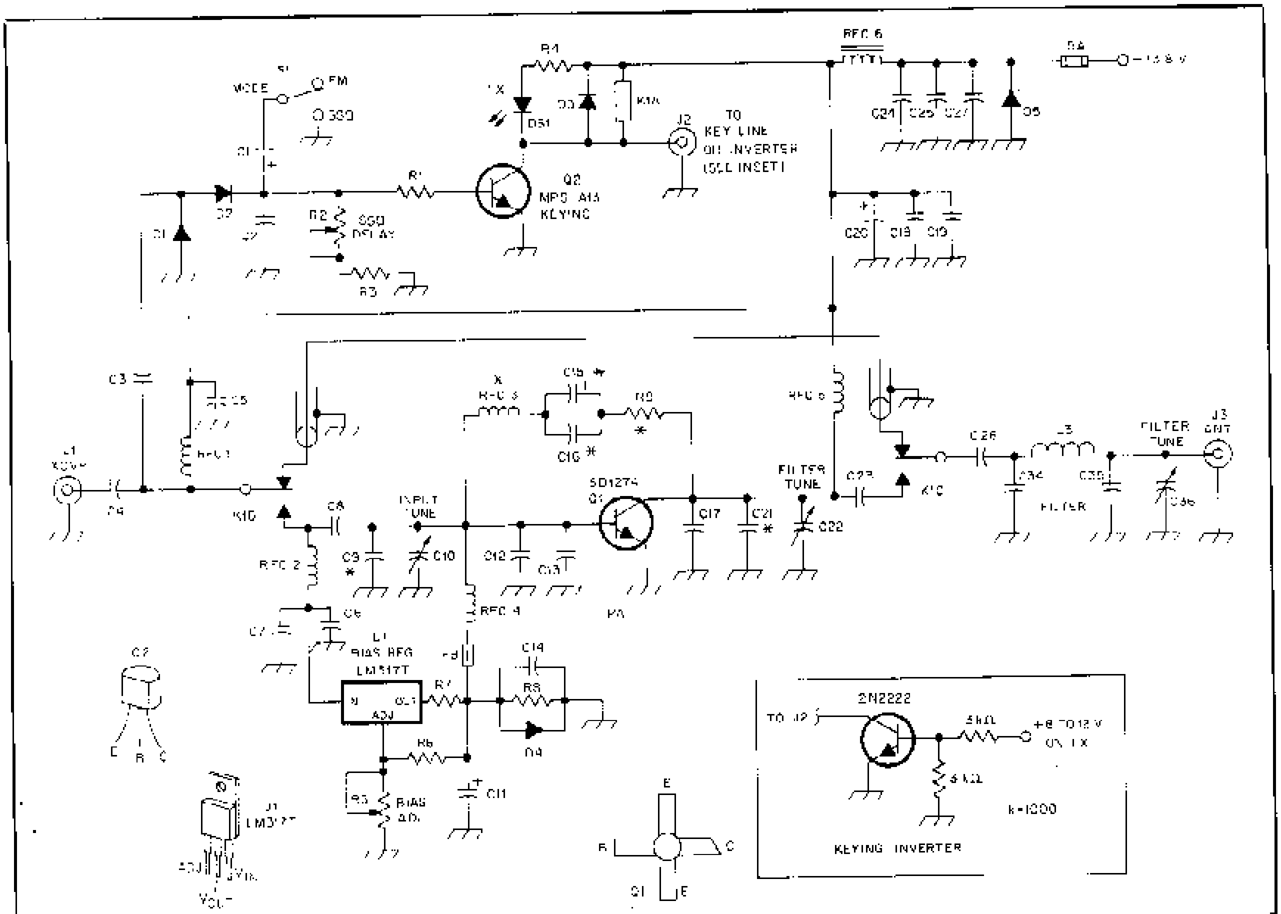



Fig 1—Schematic of the 25-W VHF amplifiers. The 5-A fuse is included in the power lead (external to the amplifier). Be extremely careful when mounting the power transistor—see text for precautions. In the parts list below, values for the 220-MHz version are given in parentheses where they differ from those in the 2-meter version. Asterisks indicate parts not used in the 220-MHz version.

C1—15-µF, 6-V dc.
C2—470-pF disc.
C3—2-pF silver mica.
C4, C23, C26—270- to 470-pF silver mica or Unelco.
C8—270- to 470-pF (100 pF) silver mica or Unelco.
C5, C7, C14, C16, C19, C24—0.01-µF disc.
C6—0.22-µF disc.
C9—43-pF silver mica or Unelco.
C10—Arco 404—4 to 60 pF (Arco 403—4 to 40 pF).
C11, C15*—1-µF, 15-V tantalum.
C12—180-pF (120-pF) Unelco.
C13, C18—220-pF Unelco.
C17—68-pF (51-pF) Unelco.
C20—10-µF, 35-V electrolytic.
C21*—33-pF silver mica or Unelco.
C22—Arco 404—4 to 60 pF (Arco 402—1.5 to 20 pF)
C25—0.1-µF disc.
C27—0.001-µF disc.
C34, C35—25-pF (18-pF) Unelco.
C36—10-pF trimmer.
D1, D2—1N4148 or IN914.
D3, D4—1N4001 or equiv.
D5—ECG 581 or equiv.
DS1—LED.
FB—Ferrite bead.
K1—Omron LZN203-UA-DC12 DPDT relay.
L3—3 turns (1 turn) no. 18, closewound, 0.2-in. (¼-in.) ID.
Q1—Thomson/Mostek SD1274.
Q2—MPS-A13 NPN Darlington.
R1, R4—1.5-kΩ, ¼ W.
R2—500-kΩ, 10-turn potentiometer.
R3—10-kΩ, ¼ W.
R5—100-Ω miniature potentiometer.
R6—270-Ω, ¼ W.
R7, R8—10-Ω, ½ W.
R9*—15-Ω, ¼ W.
RFC1, RFC2, RFC4—0.47-µH molded choke.
RFC3*—0.15-µH molded choke.
RFC5—6 turns (5 turns) no. 16 enam, ¼-in. ID.
RFC6—VK200/4B ferrite choke.
S1—Miniature SPDT toggle.
U1—LM317T voltage regulator

*Miscellaneous*

2 BNC or N connectors (see text).
4 x 4 x 1½-in. heat sink.
5-A fuse and in-line holder.
2 x 1-in. scrap of thin sheet brass.

Driving the amplifier with my ICOM IC-3AT on high power (about 1.5 W), the amplifier puts out 20 W. With the IC-3AT on low power (about 150 mW), I can tune the amplifier to give 4 W output. Efficiency is about the same as the 2-meter version.

The saturated power output for both versions is more than 35 W in FM operation. The maximum FM power input is 4 W. Minimum power input for proper RF-sensed keying operation is 100 mW.

### The Power-Amplifier Circuit

See Fig 1. K1 is similar to relays used in VCR RF circuits. I have switched up to 40 W at 2 meters and 35 W at 220 MHz with these relays. They present a good match to 50 Ω. The loss through the amplifiers (when not in use) resulting from these relays is less than 1 dB. This is typical for 2-meter and 220-MHz amplifiers.

In addition to switching the transmitted and received signals, the relays also switch the dc supply voltage. In the transmit mode, K1 switches 13.8 V dc to the input of the bias regulator, U1. The regulator IC and its associated resistors (R7, R8) and bias diode (D5) supply a stiffer bias voltage to the base of Q1 than the more-common voltage-divider bias networks. This low-

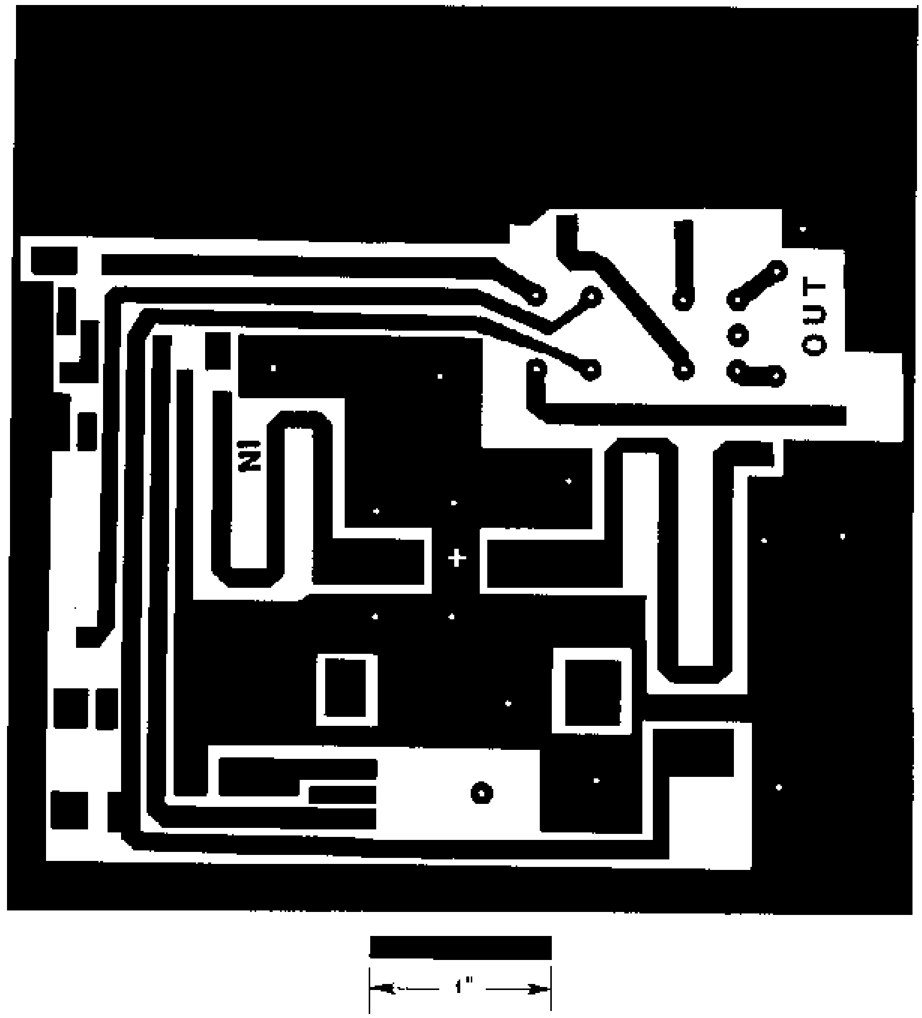



Fig 2—Main PC-board layout for the 2-meter and 220-MHz amplifiers. Artwork is full scale. Because this is a microstripline design, do not change the geometry or routing of board traces. The board must be drilled for rivets, mounting hardware and transistor mounting at the locations marked. The transistor-mounting hole is 0.38-in. diam and should be drilled at the + near the center of the PC board. All other holes (except for the relay-mounting holes near the output microstripline) are for rivets and no. 4-40 mounting hardware.

impedance bias source keeps the bias voltage constant over the range of RF drive levels. With a voltage-divider bias network, bias voltage can be upset by the base-emitter rectification (self bias) developed by the RF driving signal. In such a case, overdriving the amplifier causes the base bias to decrease, resulting in non-linear amplification. This effect is limited with the regulator-type bias circuit used in these amplifiers.

TR switching is accomplished by an RF sensing circuit. A small amount of RF is sampled by C3 and rectified by D1 and D2, which turns on keying transistor Q2. Q2 pulls in K1, which switches the amplifier into the line.

When S1 is in the SSB position, a short drop-out delay is added in the RF sensed-keying circuit to keep the amplifier keyed during brief pauses in speech. This delay is adjustable by varying R3. In the FM position, no delay is needed. S1 does not change the class of operation of Q1—it merely switches in the delay circuit.

The switching relays are wired so the amplifier can remain in-line at all times, with or without the supply voltage connected. Applying the supply voltage allows you to use the amplifier and preamp. Without the supply voltage connected, all transmitted and received signals pass through the amplifier.

The spectral output of these amplifiers is quite good, but to ensure clean signals, I've added filters to the output of each unit. Although there isn't much extra room for the filter components inside the amplifier cabinet, you can mount them on the back cover or in another small enclosure. The filters, shown in the title photo, are very simple to build and tune.

### Construction

Each amplifier consists of two PC boards: the power-amplifier board and the preamp board (if used). After the PC boards are etched, holes are drilled with a no. 50 bit for installation of tinned grounding rivets at all RF and dc grounds (see Fig 2).[2] Install the rivets on the board as follows: After inserting the rivets, flare the inserted end with an awl. Next, flatten the rivet by tapping it lightly with a hammer, using an anvil or other solid surface under the PC board as a support. Solder the rivets on both sides of the PC board. Alternatively, pieces of wire can be soldered through the board -but because the wires will not be flush with the board, mounting the heat sink may be difficult.

Drill the holes for Q1 and the board-mounting screws as indicated in Fig 2. No holes are needed for component mounting because all parts are mounted on the trace side of the PC board. All the components except the preamp board are mounted next. (The preamp board is mounted after the amplifier has been tested, to prevent possible damage to the preamplifier.) Connect a piece of miniature 50-Ω Teflon® or RG-58 coaxial cable between K1 and the amplifier-input microstripline (see Fig 3).

After drilling or milling holes for Q1 in a suitable heat sink (see Fig 4), tap the mounting holes in the heat sink for no. 4-40 hardware, and mount the PC board to the heat sink. Trim the four leads of Q1 to about half their original length to make mounting easier.

Q1 can be mounted in one of several ways. The distance between the underside of the leads of Q1 and the heat-sink mounting area of Q1 is larger than the thick-

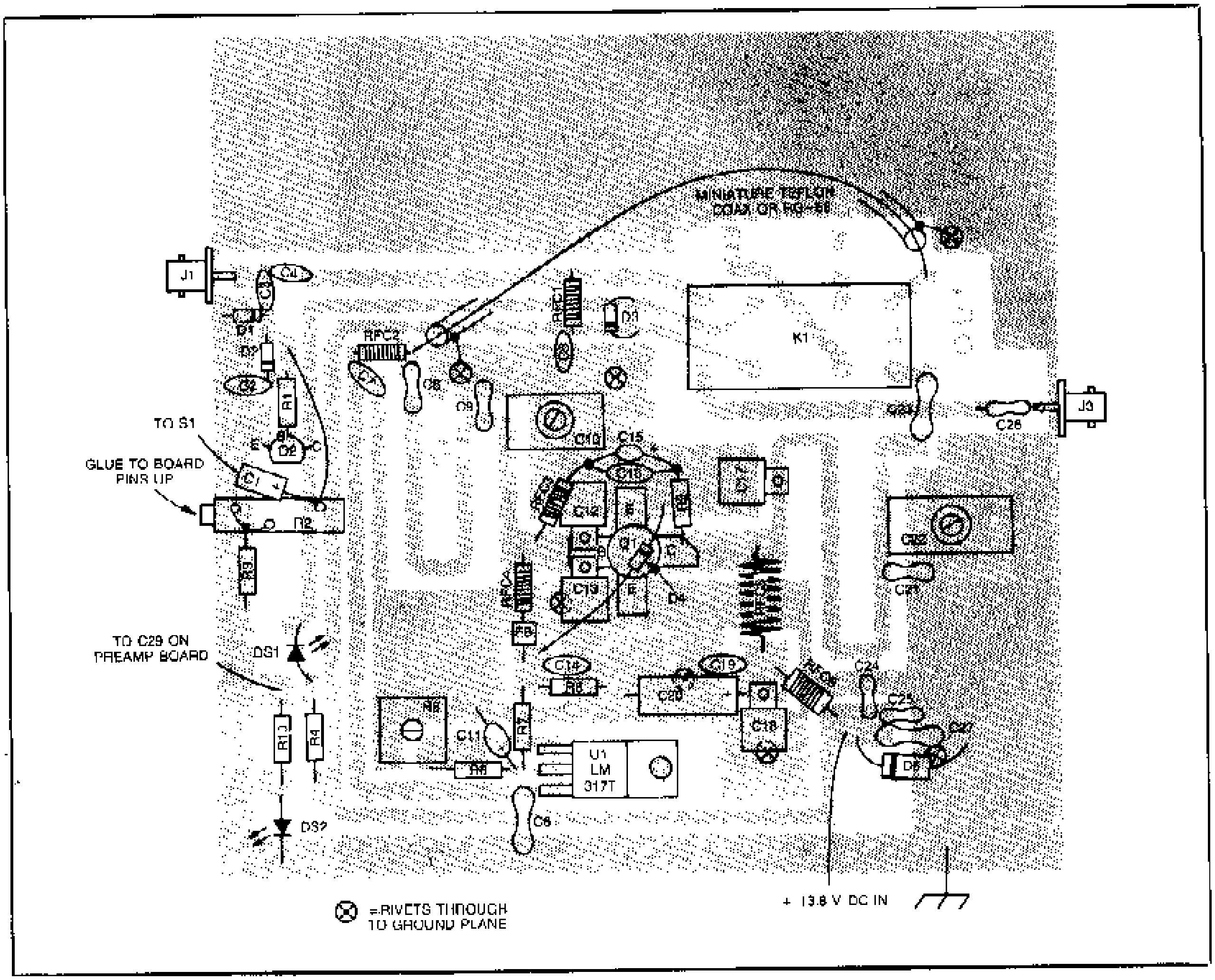



Fig 3—Parts-placement diagram for the VHF amplifiers. All parts are mounted *on the foil-trace side* of the PC board. The power-transistor mounting stud passes through the board and into the heat sink. D6 is epoxied to the ceramic cap of Q1. R2 (10-turn potentiometer) is epoxied to the PC board as indicated, with the pins facing up.

ness of 1/16-in. G-10 board material. Because of this, the heat sink must be milled (see Fig 4), or small pieces of copper or brass must be soldered under each lead of Q1 to make up the difference in height. Alternatively, a second piece of G-10 material can be cut to the same size as the amplifier PC board and used as a spacer between the PC board and heat sink.

Be careful not to crack the body of Q1 where the leads of the device meet it—this can release beryllium-oxide (BeO) dust, *which is lethal.* The leads of the transistor can be bent down slightly to the PC board without affecting RF performance, but *never* force them in the opposite direction after the transistor has been tightened to the heat sink. Mount the transistor to the heat sink *first*, then solder its leads to the board, and *not vice versa.* Use thermally conductive compound between Q1's mounting surface and the heat sink.

Cut a piece of hobby-store sheet brass about as wide as the bias regulator IC and twice as long as the body of the device. This will be a heat sink for the bias regulator. When mounting the regulator IC, use thermally conductive compound between it and the brass sheet, and between the brass and the main PC board. After tightening the IC hardware to the PC board, bend the brass sheet in a U shape over the IC, leaving enough clearance for heat to escape between the IC and the brass heat sink. This heat-sink arrangement can be seen near the bottom center of each amplifier in the lead photograph.

### The Preamplifier Circuit

The high gain and low noise figure (NF) of a GaAsFET preamp are not necessary in amplifiers in this power class. I designed the preamp circuit (Fig 5) to use an inexpensive U310 FET. It has more than enough gain to overcome the losses of the amplifier switching circuits and the feed line to the amplifier. The preamp has more than 12 dB gain and noise figure of about 2 dB.

When S2 is closed, K2 closes, activating the preamplifier by applying the dc supply voltage to the drain circuit of Q3 and to the preamp ON LED, DS2. In the transmit mode, K1 switches off the supply voltage to K2, allowing K2 to drop out.

The preamp circuit is optional, and I didn't include it on the main amplifier PC board. If you're not going to build the preamp, solder foil-tape or wire jumpers between the two points on the main amplifier PC board where the preamp connects during assembly.

### Building the Preamplifier

The schematic of the preamplifier circuit is shown in Fig 5. As mentioned earlier, although some component values differ between the 2-meter and 220-MHz versions, the two are essentially the same in all other respects. Components that have different values for the two versions are marked with

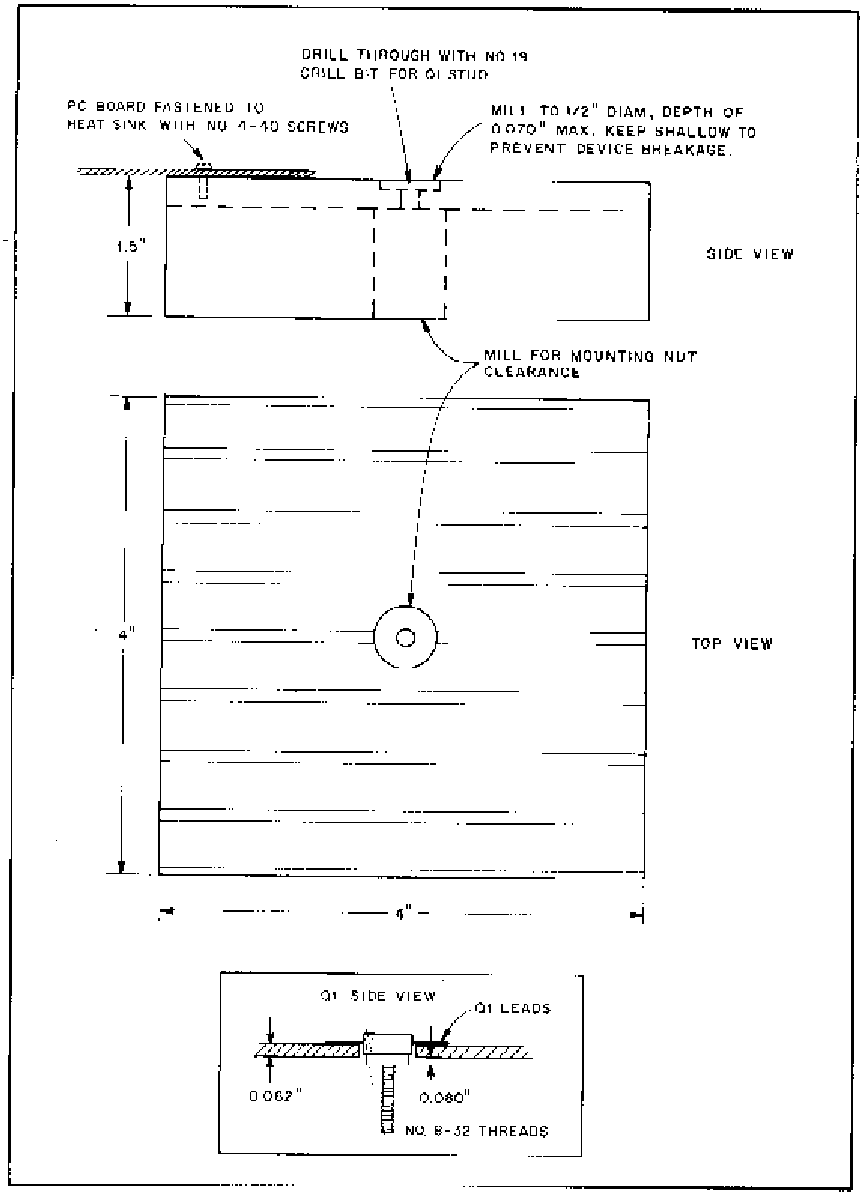



Fig 4—Heat-sink drilling dimensions for the VHF amplifiers. Overall heat-sink size isn't critical, but should be close to the dimensions shown. As an alternative to milling the heat sink to accept Q1, a piece of 1/16-in. double-sided PC-board material can be used as a shim. Be careful not to stress the transistor lead to-body connections during mounting.

asterisks on the schematic and the parts list. Unlike the main amplifier PC board, most preamp components are mounted through the board and soldered on the bottom side. The PC-board layout and parts-placement diagrams are shown in Figs 6 and 7, respectively.

As with most FET VHF preamplifiers, a shield is necessary between the input inductor and the active device. Solder a piece of scrap brass sheet to the ground foil between these circuit elements. (This preamp shield can be seen in the right-hand amplifier in the lead photo, just behind L1.)

After building the preamplifier, tune it for maximum gain with a signal generator or an on-the-air signal. If one is available to you, use a noise-figure meter and tune the preamp for best NF.

**Building the Output Filters**

I built the output filters for each amplifier on scraps of PC-board material. The construction is shown in the title photo. After building the filters, it's a good idea to use some silicone sealant on the coil (especially in the 2-meter filter) to hold the coil turns in place. Install the filter in a suitable enclosure, or in the amplifier cabinet.

To tune the filters, you'll need a receiver capable of receiving the second harmonic of the fundamental (288 MHz for the 2-meter filter, and 440 MHz for the 220-MHz filter), and a signal generator or an on-the-air signal. Connect the filter between the antenna (or signal generator) and the receiver, and tune C36 for minimum second-harmonic signal level.

**Enclosures**

I used the main amplifier PC board as the top cover for the unit (with the heat sink mounted on it). I made the sides and bottom cover of the enclosure from PC-board material. The side walls are soldered to the amplifier board, and the bottom cover is attached to the side walls with small brackets (also made of PC-board material) soldered to the bottom cover. Alternatively, the amplifier can be mounted in an aluminum enclosure.

Although I used BNC connectors for RF input and output, N connectors can also be used. Make the connections from the input connector to the PC board with a piece of no. 16 wire or a 1/8-inch-wide strip of brass to the input microstripline. At the output, connect dc-blocking capacitor C26 between the microstripline and the antenna connector. Check the board for proper component placement and good solder joints, and get ready to tune up the amplifier!

**Amplifier Tune-Up**

As with the amplifier-circuit design and description, the tune-up procedure is very similar for both. The only difference is the exciter you use. Here's how to tune either version.

Disconnect RFC4 from the base of Q1. Connect a voltmeter to the free end of RFC4. Apply 13.8 V dc to the amplifier supply voltage leads. Using the voltmeter, verify that R5 is mounted so that output of U1 increases with clockwise rotation of R5. Turn R5 fully counterclockwise (minimum U1 output voltage). Reconnect RFC4.

Set the quiescent (no-drive) current to Q1 as follows: Disconnect one end of RFC6 and connect an ammeter in series with it. Apply 13.8 V dc to the amplifier through a 5-A fuse. Turn the preamp off. *Do not apply RF drive during this adjustment.* Using a clip lead, ground the collector of Q2. This should actuate K1. Check the TX LED, DS1, for operation. (If K1 actuates and the TX LED does not light, the LED may be installed in reverse.) Slowly adjust R5 for an idling current (through RFC6) of 75 to 100 mA. The amplifier should be stable; instabilities are indicated by erratic variation of Q1's quiescent current as R5 is adjusted.

Disconnect the ground lead of Q2. Q1's collector current should drop to zero. If the collector current does not drop to zero, the amplifier is unstable. If all is well, remove the ammeter and reconnect RFC6. If the amplifier is unstable, check all bypass capacitors and solder connections.

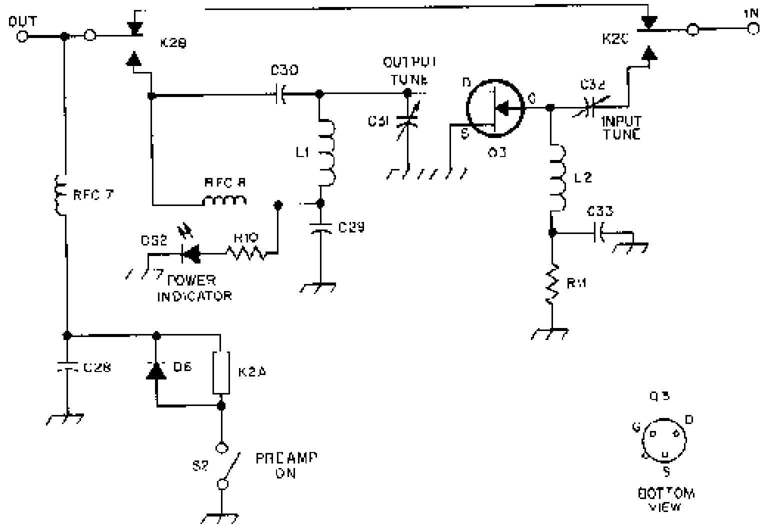
Apply about 100 mW of drive to the amplifier and check that the COR and delay circuits work properly. Adjust C10 and C22 for maximum power output. Increase drive power and retune for maximum output.

Fig 5—Schematic of the preamplifier circuit. K2 is identical to K1 on the main amplifier board. S2 and DS2 are mounted on the front panel of the amplifier. In the parts list below, values for 220-MHz version are given in parentheses where they differ from those of the 2-meter version.

C28, C29, C33—0.01-µF disc.
C30—2-pF silver mica.
C31, C32—20-pF trimmer.
DS2—LED.
D6—1N4001.
L1, L2—5 turns (4 turns) no. 16 enam, 0.3-in. ID.
K2—Omron LZN203-UA-DC12 DPDT relay.
Q3—U310 FET.
R10—1.5-kΩ, ¼ W.
R11—91-Ω, ¼ W.
RFC7, RFC8—0.47-µH molded choke.
S2—Miniature SPDT toggle.

*Miscellaneous*

1 × ½-in. strip of thin sheet brass



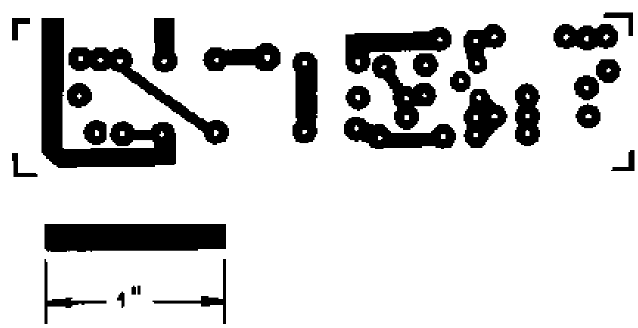




Fig 6—Full-size PC-board layout for the preamplifier circuit. Unlike the power-amplifier PC board, most of the preamplifier components are mounted on the non-trace side of the board.

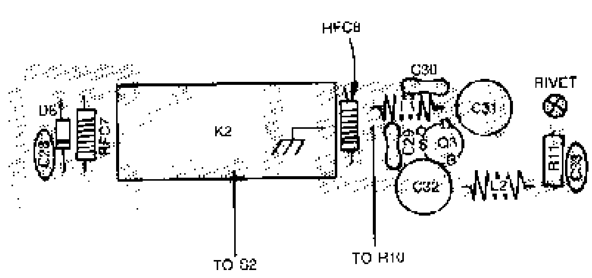



Fig 7—Parts-placement diagram for the VHF preamplifier. Mount all components on the unetched ground-plane side except for C30 and C31. Use a drill to clear the foil away from all mounting holes on the ground-plane side of the board (except for through-board ground connections). Solder all ground connections on *both* sides of the PC board (see text for rivet-installation instructions). Solder a brass-strip shield to the ground foil between L1 and Q3 on the component side of the PC board.

After final assembly, tune the amplifier for the desired frequency and power level.

**Final Assembly**

The preamplifier board can now be installed on the main PC board. Mount the preamp on its edge (refer to the title photo and Fig 3) and solder the input and output microstriplines in place. Solder the ground foil of the preamp board to the ground foil of the main board in a few places to support the preamp board. Connect S2 and DS2 to the preamp board with hook-up wire (see Figs 5 and 6 for connection points). Apply power and check for proper operation of S2, K2 and DS2.

The enclosure can now be painted if you wish. Use masking tape to cover the connectors and heat sink. (Mount the LEDs and switches after painting.) You may want to add stick-on rubber feet to the bottom cover to keep it from sliding around and being scratched.

**Amplifier Operation**

The 2-meter amplifier works very well with my Kenwood TH 21AT hand-held and ICOM IC-202S SSB/CW transceiver. I use one in my shack and one mobile—both at more than 25 W output. I drive the 220-MHz version of the amplifier with an ICOM IC-3AT (in its high-power mode).

Limit the amplifier power output to 25 W during linear operation. *All SSB amplifiers have a rated linear power output that should not be exceeded, even though the amplifier may be driven above that level. To keep your signal clean, do not overdrive any amplifier.* For exciters with fixed power outputs that would overdrive the amplifier,

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# 25-W Linear Amplifiers

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use the loss of a length of RG-58, or a discrete attenuator, between the radio and the amplifier to prevent overdrive. The gain of the preamplifier (if used) will overcome the attenuator or cable loss during receiving.

When using any amplifier or transverter in the shack, it is a good practice to "hard key" it. Hard keying is simply forcing the amplifier or transverter into the transmit mode with a switch closure or an applied voltage. To do this, run a keying line from the exciter to the amplifier. (Ground the collector of Q2 to hard key these amplifiers.) I added a phono jack to the 220-MHz amplifier to facilitate hard keying. If a positive voltage is used for keying, a 2N2222 transistor inverter can be used between the transceiver and the collector of Q2 (see the inset in Fig 1).

### Summary

These amplifiers have served me well in the car and at home. After building one of these amplifiers, you'll probably find what I did: They're so handy to have around, and so easy to build, that you can't build just one!

### Notes

[1]Thomson Components/Mostek Corp, Semiconductor Division, Commerce Dr, Montgomeryville, PA 18966. Thomson transistors are available through RF Gain, Ltd, 100 Merrick Rd, Rockville Center, NY 11570, tel 516-536-8868 or 800-645-2322.

[2]The following parts are available from Frontier Microwave, RD 1 Box 467, Ottsville, PA 18942: 100+ tinned rivets: $2; relays (K1, K2): 2 for $8. Prices include shipping. The ARRL and *QST* in no way warrant this offer.